

Arch-Taping Techniques for Altering Navicular Height and Plantar Pressures During Activity

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Context: Arch tapings have been used to support the arch by increasing navicular height. Few researchers have studied navicular height and plantar pressures after physical activity.

Objective: To determine if taping techniques effectively support the arch during exercise.

Design: Crossover study.

Setting: Athletic training research laboratory.

Patients or Other Participants: Twenty-five individuals (13 men, 12 women; age = 20.0 ± 1.0 years, height = 172.3 ± 6.6 cm, mass = 70.1 ± 10.2 kg) with a navicular drop of more than 8 mm (12.9 ± 3.3 mm) volunteered.

Intervention(s): All individuals participated in 3 days of testing, with 1 day for each tape condition: no tape, low dye, and navicular sling. On each testing day, navicular height and plantar pressures were measured at 5 intervals: baseline; posttape; and after 5, 10, and 15 minutes of running. The order of tape condition was counterbalanced.

Main Outcome Measure(s): The dependent variables were navicular height in millimeters and plantar pressures in kilopascals. Plantar pressures were divided into 5 regions: medial forefoot, lateral forefoot, lateral midfoot, lateral rearfoot,

and medial rearfoot. Separate repeated-measures analyses of variance were conducted for each dependent variable.

Results: Navicular height was higher immediately after application of the navicular-sling condition ($P = .004$) but was reduced after 5 minutes of treadmill running ($P = .12$). We observed no differences from baseline to posttape for navicular height for the low-dye ($P = .30$) and no-tape conditions ($P = .25$). Both the low-dye and navicular-sling conditions increased plantar pressures in the lateral midfoot region compared with the no-tape condition. The low-dye condition created decreased pressure in the medial and lateral forefoot regions compared with the no-tape condition. All changes were identified immediately after application and were maintained during running. No changes were noted in plantar pressures for the no-tape condition ($P > .05$).

Conclusions: Both taping techniques effectively changed plantar pressures in the lateral midfoot, and these changes were sustained throughout the 15 minutes of exercise.

Key Words: navicular-sling taping, low-dye taping, running, barefoot

Key Points

- The arch-taping techniques redistributed plantar pressure more effectively than they changed navicular height.
- Both arch-taping techniques shifted plantar pressures laterally to increase pressures on the outside of the foot, and the changes were maintained throughout the 15-minute exercise period.
- More attention should be placed on how arch-taping techniques change plantar-pressure distribution.
- Plantar pressures may be a more clinically relevant measure of foot motion.
- Plantar pressures were decreased in the medial and lateral forefoot with the low-dye taping technique and were increased in the lateral midfoot with the low-dye and navicular-sling taping techniques.

The foot is one of the most complex appendages of the human body. Its 26 bones (7 tarsals, 5 metatarsals, and 14 phalangeal segments) create 3 distinct areas of the foot known as the *rearfoot*, *midfoot*, and *forefoot*. The foot goes through many biomechanical changes during walking, running, and standing. Throughout a normal stride, the foot moves from a pronated position, which enables it to dampen ground reaction forces and adapt to uneven terrain, to a supinated position, which creates a rigid lever that propels the body forward.^{1,2}

Pronation typically occurs between the heel-strike and midstance phases of the gait cycle. During pronation, the tibia internally rotates, the calcaneus everts, and the talus adducts and plantar flexes. This motion also causes the alignment of the 2 axes of the midtarsal joint to become

more parallel, which allows the foot to adapt to uneven surfaces. For these reasons, some pronation is required for normal ambulation; however, when pronation becomes excessive, overuse injuries can occur. Excessive pronation (overpronation) places increased stress on the foot and ankle structures as both static and dynamic stabilizers work to maintain the shape of the foot.³ Specifically, the tibialis posterior contracts concentrically to facilitate inversion and supination of the foot and eccentrically to control eversion and pronation.⁴ Based on the insertion site on the navicular and medial cuneiform, the tibialis posterior muscle also acts to support the medial arch. Therefore, when repetitive overpronation occurs, injuries such as medial tibial stress syndrome³ and plantar fasciitis can occur.⁵

Researchers^{6,7} have reported that arch tapings are a good temporary treatment for athletes with pain or injury due to overpronation. If athletes respond well to the use of arch-taping techniques, more permanent solutions, such as orthoses, can be implemented. Arch tapings are meant to provide temporary external support for the medial longitudinal arch.^{6,7} As the foot bears weight, the tape helps maintain the shape and height of the arch, preventing it from falling medially. The strapping also reduces motion at the midtarsal joints (talonavicular and calcaneocuboid joints), altering how the forefoot adapts to the ground and reducing the amount of pressure placed on that region.⁸ Many taping techniques have been reviewed in the literature.⁹⁻¹⁴ Some of the more commonly used arch tapings have been the low-dye,^{9,10,13} X-arch,^{9,12} and high-dye^{10,11,14} techniques. Whereas these taping techniques were successful in initially increasing navicular height, this change was not maintained during exercise. Most researchers have reported that after a short time (about 10–20 minutes), the arch taping lost its effectiveness to support the height of the medial longitudinal arch.^{9,12,14,15}

Other less commonly used taping techniques, such as the navicular sling, and techniques applied with a variety of materials, including white cloth tape,^{9,16} more rigid tape (eg, Leukotape [BSN Medical GmbH, Hamburg, Germany]¹⁷), or more flexible tape (eg, elastic fabric tape), need to be investigated. The low-dye technique has been a major focus of arch-related research and has been considered a criterion standard in arch-taping techniques. Therefore, the purpose of our study was to examine 3 questions: (1) How long do the low-dye and navicular-sling techniques effectively support the medial longitudinal arch during running? (2) Is the traditional low-dye technique more effective than the navicular-sling technique in raising navicular height? (3) What effects do the navicular-sling and low-dye techniques have on plantar pressures? We hypothesized that based on its increased lever arm, the navicular sling would provide greater support to the medial longitudinal arch.

METHODS

Participants

Twenty-five individuals (13 men, 12 women; age = 20.0 ± 1.0 years, height = 172.3 ± 6.6 cm, mass = 70.1 ± 10.2 kg) from a college-aged population volunteered for this study. All participants met the inclusion criteria of having a navicular drop of more than 8 mm (12.9 ± 3.3 mm). Mueller et al¹⁸ measured healthy individuals and reported a mean navicular drop of approximately 7 mm for the right foot. Therefore, we used 8 mm to reflect a sample with some degree of overpronation that could be affected by the use of a taping technique. Participants had no reported history of substantial lower body injury in the 6 months before the study that would affect gait and no acute injury, such as a sprain or strain. An *acute injury* was defined as any injury that currently caused symptoms of pain, swelling, or reduced function. Participants were also *physically active*, which was defined as performing 30 minutes of cardiovascular exercise at least 2 days per week to ensure that they could complete the testing protocol. All participants provided written informed consent, and the



Figure 1. Navicular-height caliper measuring from the floor to the marked navicular tuberosity.

study was approved by the Indiana University Institutional Review Board.

Instrumentation

A Vernier height caliper (model 506-207; Mitutoyo, Kawasaki, Japan) was used to measure navicular height (Figure 1). The units of measurement were millimeters, with a gradient spacing of 0.02 mm. This instrument has been used in previous studies and has been shown to be reliable.¹⁹⁻²¹ Menz,¹⁹ Kelly,²⁰ and Saltzman et al²¹ reported that the caliper had good intrarater reliability, with intraclass correlation coefficients (ICCs) [2,k] ranging from 0.78 to 0.95. We used the HR Mat VersaTek System (model HRV1; Tekscan Inc, Boston, MA) to capture footprint mapping information. Peak plantar pressures were observed and recorded using the HR Mat research software. The plantar pressures are expressed in kilopascals (kPa).

Procedures

Participants were tested on 3 days, 1 for each condition. To prevent fatigue and allow the tissues affected by the tape to return to their normal states, a period of at least 24 hours separated testing days. Tape conditions were no tape, the low-dye technique, and the navicular-sling technique. The order of testing conditions was randomized for all participants. On the first day of testing, navicular drop was measured in both feet. The foot that exhibited the largest navicular drop was used for all taping and testing for the remainder of the study.

The following procedures were repeated on each of the 3 testing days. First, navicular height and plantar pressures were measured. Second, 1 of the 3 taping conditions was applied, and navicular height and plantar pressures were measured again. Participants completed 15 minutes of barefoot jogging on a treadmill (Marquette 2000; Marquette Electronics, Inc, Milwaukee, WI). Every 5 minutes, they stopped running, and we measured navicular height and plantar pressures. The treadmill speed was self-selected by the participant and was recorded and used for each of the 3 testing days. Mean treadmill speed was 8.1 ± 1.3 km/h.

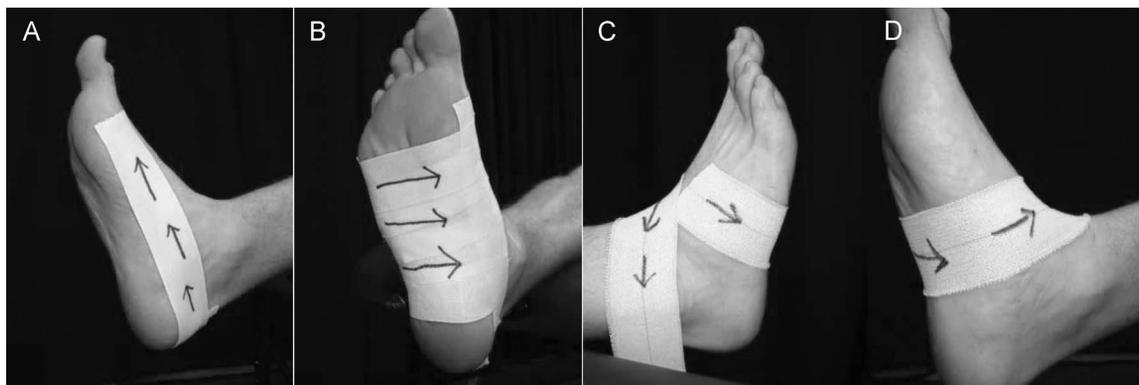


Figure 2. Taping techniques. Low-dye technique: **A**, an anchor strip around the periphery of the foot, and **B**, plantar strips pulling the arch lateral to medial. Navicular-sling technique: **C**, lateral view showing the tape traveling under the foot, and **D**, medial view showing the tape pulling upward on the navicular and the arch.

Navicular-Drop Procedure. Using butcher-block paper, we constructed a template for each participant before measuring navicular drop. The purpose of this template was to ensure consistent foot placement for the testing position each time navicular height was measured. The participants marched in place 10 times to make sure they exhibited a natural pattern, and we instructed them to stand in a bipedal stance while the feet were traced.

After the template was made, the navicular tuberosity was palpated and marked with a permanent marker. We used a ruler to measure the position of the navicular tuberosity from the posterior aspect of the foot. To measure navicular drop, participants placed their feet in the template footprints and sat on a wooden box while the foot being measured was placed in a subtalar-joint-neutral position. Subtalar-joint neutrality was determined by palpating the medial and lateral aspects of the talus under the medial and lateral malleoli until both points were equally prominent. Participants were instructed to hold this position. Using the height caliper, we measured and recorded the distance from the floor to the navicular tuberosity (Figure 1). Next, participants were instructed to stand in a relaxed position with even weight distribution on both feet. We measured the distance between the floor and the navicular tuberosity again. Navicular drop was calculated by subtracting the standing measurement from the seated measurement. Navicular drop was measured by the same researcher (T.N.) on all occasions.

Navicular Height. Navicular height was measured with procedures similar to those used to obtain navicular drop. We instructed participants to stand comfortably in the template footprints. The distance from the floor to the navicular tuberosity was measured while they stood (Figure 1). We took this measurement 3 times and recorded the mean as the navicular height for that time. Between trials, participants marched in place and were instructed to return to a comfortable stance. The caliper was also returned to zero between trials. Navicular height was measured by the same researcher (T.N.) on all occasions.

Pressure Mat. The plantar-pressure data were collected with participants in a single-legged stance. The pressure mat was calibrated for each participant. We entered his or her mass and instructed the participant to stand in a single-legged stance on the testing limb until calibration was completed. During testing, participants stood in a single-

legged stance, holding a bar for balance, for approximately 10 seconds while the footprint video was recorded. We instructed them to keep their feet facing straight and to keep their feet over a tape marker to ensure consistent placement for each trial.

Tape Conditions. We used 3 tape conditions: low dye applied with white cloth tape (Coach; Johnson & Johnson Consumer Products, Inc, New Brunswick, NJ), navicular sling applied with elastic tape (Elastikon; Johnson & Johnson Consumer Products, Inc), and no tape. The white tape was 1.5 in (3.81 cm) wide, and the elastic tape was 2 in (5.08 cm) wide. The area that was taped was clean, dry, and shaven. All tapings were performed by the same experienced certified athletic trainer (T.N.), and the navicular tuberosity was identified with a permanent marker after tape application. Aerosol adhesive spray (Cramer Tuff-skin; Cramer Products Inc, Gardner, KS) was used over the area that was taped, and all tape was applied directly to the skin to aid in adherence.

We used the traditional low-dye taping technique because this basic and simple arch taping is commonly used in the clinical setting. It is considered to be the criterion standard in arch taping compared with the underresearched navicular-sling taping. The low-dye method described by Beam⁶ was performed using only 1.5-in (3.81-cm) tape. Participants placed their feet in a neutral position, and we applied tape to the skin over the lateral surface of the fifth metatarsophalangeal joint, continuing around the heel and finishing on the medial surface of the first metatarsophalangeal joint. We applied 1.5-in (3.81-cm) tape strips to the plantar aspect of the foot (Figure 2B). The strips were applied to the lateral anchor, pulled medially across the arch, and finished on the medial dorsum. To provide maximum support, the investigator grasped the lateral aspect of the foot and applied pressure to anchor the tape before pulling it across the plantar surface. The strips continued up the plantar aspect of the foot, overlapping by half and finishing on the metatarsal head proximal to the metatarsophalangeal joints. These strips covered the outer anchor but did not encircle the entire foot (Figure 2A). Another anchor strip starting at the lateral aspect of the foot was applied to close off the plantar strips applied. This strip was applied in the same manner as the first anchor strip. The investigator applied 2 additional anchor strips. These strips overlapped by half and were applied to the dorsal

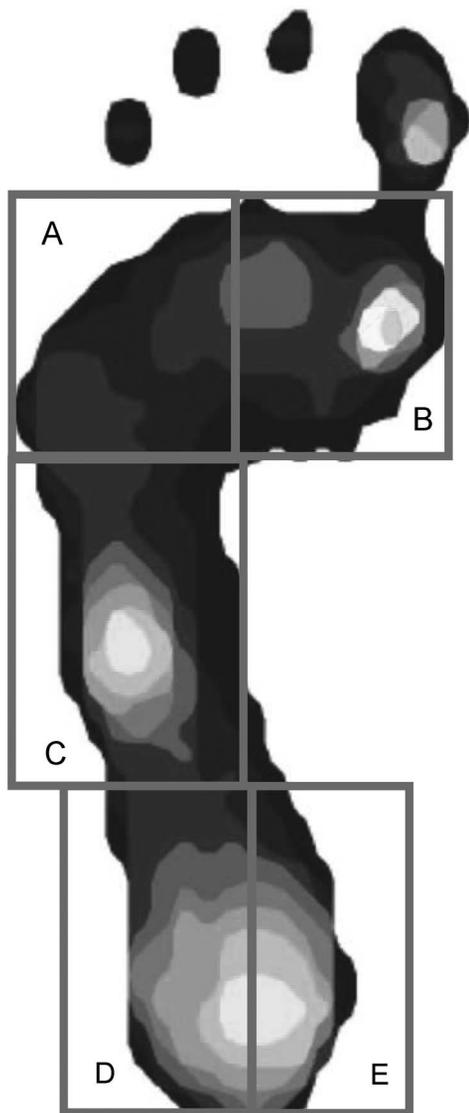


Figure 3. Plantar-pressure composite shot with masks included. A, Lateral forefoot. B, Medial forefoot. C, Lateral midfoot. D, Lateral rearfoot. E, Medial rearfoot.

aspect of the foot. The strips started on the medial dorsum and were pulled laterally, ending on the anchor that covered the fifth metatarsal.

The navicular-sling technique was performed using 2-in (5.08-cm) elastic tape. Starting on the dorsum of the foot, the tape was pulled laterally across the metatarsals and continued over the fifth metatarsal (Figure 2C). The tape traveled under the foot on the plantar surface, medially toward the first metatarsal, and up under the navicular (Figure 2D). The tape continued to the dorsum of the foot and crossed over the lateral malleolus as it wrapped around the ankle. Traveling around the ankle and covering the medial malleolus, the tape ended on the dorsum of the foot where it began. A second strip of elastic tape was applied in the same fashion to provide more stability. The technique was completed with 2 strips of white cloth athletic tape. These strips were used to anchor the end of the elastic tape and close the taping, holding the end down so it did not unravel.

A no-tape condition also was included. This served as a control condition for comparison with the other techniques.

Data Processing

Navicular-height data for each time and tape condition were recorded. Three trials for each measurement were recorded, and the mean was calculated and entered for statistical analysis.

Plantar-pressure information was processed in the HR Mat research software. The footprint was averaged in the view menu to provide a clearer image. Movie averaging was used to average the pressure value of each cell for the entire recording. This created 1 composite frame from the 400 total frames that were recorded. The composite image was used for data analysis. The movie was also recorded at a sampling frequency of 40 Hz, which fell within the 25- to 50-Hz range used in other studies.^{8,17,22,23}

Initially, the composite footprint was divided into 6 regions: medial rearfoot, lateral rearfoot, medial midfoot, lateral midfoot, medial forefoot, and lateral forefoot. We determined the regions by splitting the footprint horizontally into thirds (excluding the phalanges) and vertically splitting each of those sections down the middle. Regions were created by adding boxes to the data window and were resized to capture plantar-pressure data in each of these foot regions. The templates were saved in the participants' files for use in the other trial windows. However, given the architecture of the foot, insufficient data were displayed in the medial midfoot during the baseline measurements. Therefore, data could not be analyzed in the medial midfoot region, leaving the remaining 5 regions for statistical analysis. The composite footprint output with the regions included is shown in Figure 3. Peak plantar pressure was recorded for each region.

Statistical Analysis

Two separate repeated-measures analyses of variance (ANOVAs) were used. Navicular-height data had 2 within-subject factors: time at 5 levels (baseline, posttape, 5 minutes, 10 minutes, 15 minutes) and tape intervention at 3 levels (no tape, low dye, navicular sling). Plantar-pressure data had 3 within-subject factors: time at 5 levels (baseline, posttape, 5 minutes, 10 minutes, 15 minutes), tape intervention at 3 levels (no tape, low dye, navicular sling), and region at 5 levels (medial rearfoot, lateral rearfoot, lateral midfoot, medial forefoot, lateral forefoot). We calculated effect sizes for all analyses using the Cohen *d* (*small* ≤ 0.40 , *moderate* $\leq 0.41-0.70$, *large* ≥ 0.71).²⁴ Planned comparisons were completed to assess time-by-tape interactions for each region. For all analyses, if a baseline-to-posttape difference was found, we used Dunnett post hoc testing to evaluate the subsequent time periods. For Dunnett testing, we used the no-tape condition or baseline time as the comparison point. The a priori α level was set at .05. Data analysis was performed with SPSS statistical software (version 20.0; IBM Corporation, Armonk, NY).

In addition, we calculated ICCs to determine the reliability of the measurement techniques. The baseline measures for 2 of the test days were evaluated using ICC [2,3] to establish the relationship among all measures (navicular height and the 5 plantar-pressure regions). We

Table 1. Navicular Height (mm) at Each Time Frame (Mean ± SD)

Condition	Time				
	Baseline	Posttape	5 min	10 min	15 min
No tape	46.3 ± 7.0	46.7 ± 6.6	46.2 ± 6.7	46.1 ± 6.9	46.1 ± 6.7
Low dye	47.4 ± 6.2	48.1 ± 6.5	46.0 ± 6.9	46.1 ± 7.1	46.1 ± 7.1
Navicular sling	46.7 ± 6.4	49.1 ± 5.9 ^a	48.1 ± 5.8	47.7 ± 5.9	47.7 ± 5.9

^a Indicates an increase in navicular height between baseline and posttape ($P < .05$).

also calculated the standard error of the measurement (SEM) and minimal detectable change (MDC) for all measurements. The MDC is the amount of change required the change to be considered tangible over and above measurement error. Traditionally, MDC with 95% confidence intervals (CIs) is used, but Hopkins²⁵ suggested that 95% CIs are too strict when deciding if real change has occurred during more clinically applied measures. He recommended using 1.5 to 2.0 times the SEM rather than 2.77 times the SEM.²⁵ Therefore, we used MDC with 80% CIs = $1.81 \times \text{SEM}$.

RESULTS

Navicular Height

Means, standard deviations, and MDC values of the navicular-height measurements for all tape conditions are displayed in Tables 1 and 2. For navicular height, the results of a repeated-measures ANOVA identified a time-by-tape interaction ($F_{8,192} = 5.48$, $P = .01$, $\eta^2_p = 0.19$, power = 0.99). With the navicular-sling technique, navicular height was higher posttape compared with baseline (difference = 2.4 ± 0.5 mm; $P = .004$; 95% CI = 0.6, 4.2 mm; Cohen $d = 0.39$). This value also exceeded the MDC that was calculated for navicular height, indicating that this change is meaningful. However, after 5 minutes of running, navicular height was not different from the baseline measure ($P = .12$) and did not exceed the MDC. Therefore, we concluded that the navicular-sling technique was not successful in increasing navicular height after 5 minutes of running. For the low-dye and no-tape conditions, we observed no differences from baseline to posttape ($P = .30$ and $.25$, respectively) or at any other times ($P > .05$).

Plantar Pressures

The results of the repeated-measures ANOVA identified a tape-by-region interaction ($F_{10,240} = 7.0$, $P = .01$, $\eta^2_p = 0.23$, power = 0.99). Plantar pressures increased in the lateral midfoot region in both the low-dye and navicular-sling compared with the no-tape condition (Table 3). The

low-dye condition created a decrease in plantar pressure compared with the no-tape condition for the medial forefoot region at all times and for the lateral forefoot region at all times except 15 minutes ($P = .001$). We observed no differences in the medial or lateral rearfoot pressures for any tape condition or time ($P > .05$).

For each region, means and standard deviations are displayed in Table 3, and MDC is displayed in Table 2. Planned comparisons were calculated for each region separately to identify tape-by-time interactions. We identified a tape-by-time interaction for the medial forefoot ($F_{8,192} = 3.6$, $P = .01$, $\eta^2_p = 0.13$, power = 0.98), lateral forefoot ($F_{8,192} = 3.9$, $P = .01$, $\eta^2_p = 0.14$, power = 0.99), and lateral midfoot ($F_{8,192} = 6.0$, $P = .01$, $\eta^2_p = 0.20$, power = 0.99). Specifically, in the forefoot, a decrease in plantar pressures was observed in both the medial and lateral forefoot in the low-dye tape condition when the posttape time was compared with the baseline condition ($P = .001$ for both). The mean difference was 70.3 kPa for the medial forefoot (Cohen $d = 0.81$) and 51.3 kPa (Cohen $d = 0.71$) for the lateral forefoot; these values also exceeded the MDCs calculated for both of these regions. For the lateral forefoot, these changes were maintained during the entire 15 minutes of running and exceeded the calculated MDC. However, for the medial forefoot region, the changes were maintained for 10 minutes of running but did not exceed the calculated MDC for any times other than at the posttape time. We noted no differences for the navicular sling in either forefoot region ($P > .05$). In the lateral midfoot region, we identified an increase in plantar pressures in both the low-dye and navicular-sling conditions when the posttape time was compared with the baseline time ($P = .001$). The mean difference was 50.6 kPa (Cohen $d = 0.66$) for the low dye and 49.7 kPa (Cohen $d = 0.58$) for the navicular-sling condition, and these differences exceeded the MDCs calculated. All changes were demonstrated immediately after application and were maintained during the 15 minutes of running. We observed no differences in the medial or lateral rearfoot regions at any time for any of the taping conditions ($P > .05$). Finally, in the no-tape condition, we observed no differences for any time in any region ($P > .05$).

Table 2. Intrarater Reliability and Measurement Error for Navicular Height and 5 Plantar-Pressure Regions

Variable	Intraclass Correlation Coefficient (2,3)	Standard Error of Measurement	Minimal Detectable Change
Navicular height, mm	0.97	1.12	2.02
Medial rearfoot, kPA	0.84	45.15	81.72
Lateral rearfoot, kPA	0.85	41.11	74.41
Lateral midfoot, kPA	0.94	18.18	32.91
Medial forefoot, kPA	0.87	34.85	63.07
Lateral forefoot, kPA	0.92	22.01	39.83

Table 3. Plantar Pressures, kPA (Mean ± SD)

Variable	Time				
	Baseline	Posttape	5 min	10 min	15 min
Medial rearfoot					
No tape	255.4 ± 98.9	258.9 ± 103.8	253.8 ± 104.8	276.1 ± 129.6	274.1 ± 124.2
Low dye	280.3 ± 126.8	296.6 ± 110.3	270.9 ± 118.3	280.2 ± 115.0	261.1 ± 109.2
Navicular sling	280.0 ± 106.1	293.0 ± 127.9	285.6 ± 111.5	281.9 ± 114.0	264.5 ± 102.0
Lateral rearfoot					
No tape	240.6 ± 95.5	246.6 ± 100.0	246.0 ± 92.8	263.0 ± 118.7	259.4 ± 111.3
Low dye	265.2 ± 117.1	292.4 ± 100.4	260.4 ± 109.8	263.4 ± 97.3	253.3 ± 102.9
Navicular sling	261.8 ± 96.7	279.9 ± 116.3	277.3 ± 103.5	276.0 ± 107.3	255.5 ± 95.7
Lateral midfoot					
No tape	80.4 ± 75.2	85.2 ± 76.9	85.9 ± 81.4	84.4 ± 79.0	88.5 ± 76.3
Low dye	78.6 ± 74.8	129.2 ± 79.1 ^{a,b}	125.1 ± 76.7 ^{a,b}	120.9 ± 73.1 ^{a,b}	123.2 ± 76.3 ^{a,b}
Navicular sling	82.9 ± 74.1	132.6 ± 96.5 ^{a,b}	119.0 ± 87.5 ^{a,b}	118.8 ± 85.7 ^{a,b}	122.2 ± 90.7 ^{a,b}
Medial forefoot					
No tape	208.4 ± 102.9	200.4 ± 97.2	191.9 ± 81.3	183.4 ± 91.0	183.5 ± 82.0
Low dye	194.0 ± 88.5	123.7 ± 84.5 ^{a,b}	137.6 ± 82.0 ^{a,b}	135.9 ± 77.6 ^{a,b}	142.8 ± 78.3
Navicular sling	197.7 ± 93.5	149.8 ± 92.2	147.5 ± 79.2	151.7 ± 83.5	157.6 ± 86.7
Lateral forefoot					
No tape	194.8 ± 74.8	201.8 ± 87.4	191.6 ± 61.5	183.2 ± 78.1	180.9 ± 74.4
Low dye	190.4 ± 85.0	139.1 ± 55.7 ^{a,b}	145.6 ± 68.0 ^{a,b}	143.7 ± 60.7 ^{a,b}	149.5 ± 66.0 ^{a,b}
Navicular sling	197.3 ± 78.1	160.2 ± 78.4	154.8 ± 71.0	159.2 ± 75.7	168.2 ± 79.2

^a Indicates a change in plantar pressure from baseline ($P < .05$).

^b Indicates a difference compared with no tape ($P < .05$).

DISCUSSION

We conducted this study to determine if arch tapings are an effective technique for supporting the arch of the foot during exercise. The navicular sling effectively raised the height of the navicular immediately after taping, but the effectiveness of this technique quickly diminished after the first 5 minutes of running. However, plantar pressures may be a more clinically relevant measure of foot motion. Researchers^{8,22} have reported that changes in subtalar alignment during the stance phase of gait may lead to changes in plantar-pressure distribution. Both arch-taping techniques had similar effects on the plantar pressures of the lateral midfoot region. However, for the medial and lateral forefoot regions, only the low-dye taping technique affected plantar pressures. Overall, the low-dye taping technique decreased pressure in the medial and lateral forefoot. Both the low-dye and navicular sling taping technique increased pressure in the lateral midfoot, and these pressure changes were maintained during the exercise protocol.

Navicular Height

One purpose of our study was to determine how long the arch-taping techniques are useful in supporting the medial longitudinal arch. Our results indicated that the navicular-sling taping technique effectively supported the navicular, raising the arch by a mean difference of 2.4 mm and exceeding the expected error from baseline to posttape; however, the effect of the increase was relatively small, which should be considered when determining its clinical meaningfulness. The effects of the navicular sling also diminished quickly during exercise. After just 5 minutes, the arch height decreased by a mean difference of 1 mm, and it continued to decrease over the 15-minute session. Interestingly, the low-dye technique did not result in

improved arch height immediately after tape application. This could be due to either the type of tape that was used or the basic construction of the taping technique.

Whereas different taping techniques and research methods have been used in other studies, our results are consistent with those of investigators who examined arch-height measurements and arch taping.^{9,12–15} Ator et al,⁹ Del Rossi et al,¹² and Holmes et al¹³ reported that arch heights were greater immediately after taping; however, postexercise, arch height decreased to nearly pretape levels.

One of the major concerns in using athletic tape is that it loses its effectiveness with exercise because of diminished adherence to the skin.^{9,13} Other factors leading to the strapping becoming less effective may be a loss of tensile quality of the tape or skin movement.¹³ This may also explain why the navicular-sling technique might have resulted in an immediate increase in navicular height. The navicular-sling technique used a thicker, stronger, elastic tape that has better adhesive qualities. In addition, we noted during the testing procedures that the low-dye taping seemed to pull away from the skin as participants ran but the navicular-sling technique did not. Potential reasons for the better adherence of the navicular sling are either the type of tape used or the addition of a figure-8 fixation strap to the ankle. Investigators^{9,14,26} have noted that more complex strapping techniques maintained effectiveness for a longer period. Researchers have reported that techniques such as the double X⁹ and the modified low-dye technique with additional “reverse-6’s strips that went further up the ankle^{14,15} provided support longer than the traditional low-dye techniques. These findings agree with our observations because the simple low-dye technique without added support was less effective than the navicular-sling technique. In terms of mechanical-strapping techniques, application of the navicular sling was a more complex

strapping because it used a stronger tape material and included strips that crossed the ankle. This increased lever arm created by crossing into the ankle is similar to the modification that was added to the low-dye technique,^{14,15} which also provided more support to the arch.

Plantar Pressures

Another purpose of our study was to determine the effects of arch-taping techniques on plantar pressures. Plantar pressures are believed to provide an indirect representation of subtalar joint movement, which is very important in determining the amount of pronation occurring at that joint.²³ Any changes in subtalar alignment are thought to be represented by how the pressures are distributed across the foot.^{17,22} Both taping techniques had similar effects posttaping on the lateral midfoot region and were considered to have a medium effect, indicating clinical importance. The low dye increased by 50.6 kPa (increase of 64% compared with baseline) in the lateral midfoot, and the navicular sling increased plantar pressures in the lateral midfoot by 49.7 kPa (increase of 60% compared with baseline). For the forefoot regions, only the low-dye technique changed the plantar pressures, with a mean decrease of 70.3 kPa (decrease of 36% compared with baseline) in the medial forefoot and a large effect, indicating clinical importance, and a mean decrease of 51.3 kPa (decrease of 27% compared with baseline) in the lateral forefoot and a moderate to large effect, indicating clinical importance. The positive effects of arch tapings are clear from our results. Arch tapings are meant to reduce pressures in the forefoot and shift midfoot pressures laterally to help prevent or reduce overpronation. This is in agreement with the literature, in which researchers^{8,17,22,23,26} also reported that foot pressures were increased in the lateral midfoot because of a decrease in pronation from the arch tapings.

Researchers examining plantar pressures have studied participants who exhibited excessive pronation (navicular drop >10 mm) and have studied the use of the low-dye technique,^{8,17,22,23} including the modified low-dye technique that crossed the ankle.²⁶ Vicenzino et al²⁶ reported that the pressure changes were maintained posttaping with regular walking. Nolan and Kennedy²² observed that after 10 minutes of walking, plantar pressures in the medial and lateral forefoot regions started to return to pretape levels and continued to do so when measured at 20 minutes. However, the trend for foot pressures to shift medially to laterally in the midfoot was sustained over the 20 minutes.²²

We chose not to include the medial midfoot for data analysis because of the lack of contact area in that region for many participants during the baseline measurement. Thus, we collected data from only the lateral midfoot. We observed an increase in pressure in the lateral midfoot that may suggest both tapings effectively moved pressures to the lateral aspect of the foot.

One potential reason for the conflicting findings between the navicular-height and plantar-pressure measures could be the differences in testing positions. Navicular height was measured in a bipedal stance, whereas plantar pressures were measured in a single-legged stance. In a bipedal stance, the intrinsic muscles of the foot and ankle that help support the arch are more relaxed. However, in a unipedal

stance, those same muscles are more active to support the foot and aid in balance, which may have contributed to the plantar-pressure changes being sustained for a longer period than reported by other researchers. We specifically decided to conduct the plantar-pressure aspect of this study in a unipedal stance to replicate the single-legged-stance phase of walking.

Clinical Implications

Strapping techniques are not meant to be long-term interventions. If arch tapings successfully reduce pain or other symptoms, professionally crafted orthoses are indicated.^{9,12} Historically, many researchers have focused on navicular height when educating students about the implication of arch tapings. We believe that the academic theory behind arch-strapping techniques should include a discussion about not only navicular height but also plantar pressures. We observed that arch taping did not necessarily change navicular height but did affect plantar pressures. Both taping techniques altered plantar pressures in the lateral midfoot region; however, only the low-dye taping altered pressures in the forefoot. Arch taping is meant to shift midfoot pressures laterally (increasing pressure) to prevent or reduce overpronation. Given that both taping techniques increased pressure in the lateral midfoot, both tapings seemed to be effective. However, the navicular-sling taping is easier to perform and anecdotally more comfortable for individuals. When considering all of these factors, the navicular sling may be a better choice for some patients.

Our finding of no changes in navicular height or plantar pressures for the no-tape condition is telling about the biomechanics of the foot: the architecture of the foot does not change much with extended periods of exercise. Plantar pressures remained consistent in the no-tape condition, indicating that any changes can be attributed to the strapping techniques.

Limitations

The main limitation of our study was the potential variance in how each taping was applied. Identical applications between days and between participants are impossible with the different techniques. However, we made some attempt to correct for this by applying the navicular sling with maximum tape tension to limit variability. In addition, we did not include a sham taping condition; taping has been shown to increase motoneuron excitability, making it unclear whether the plantar-pressure changes are from the specific taping technique or due to the awareness of the tape on the foot. All participants ran on the treadmill barefoot. This was designed to remove any variables contributing to the effectiveness of the strapping, such as shoe type. Participants were also not accustomed to running without shoes, so their gait patterns may have changed while running. Another limitation was not including symptomatic individuals; these results may not extend to people with arch pain.

Areas of Future Research

Researchers should investigate the use of elastic tape for supporting the medial longitudinal arch. In our study, we

applied the elastic tape at maximal stretch; researchers should evaluate how different amounts of stretch affect how elastic tape protects and supports the ankle joint. We demonstrated that arch strapping may be an effective technique, but additional assessment needs to be performed to determine the effects it may have on rearfoot motion and other aspects of gait. Motion analysis with 2- and 3-dimensional camera systems could be used to further explain how the navicular sling affects rearfoot motion, as well as if arch tapings in general have additional effects up the kinetic chain at the knee or hip. The navicular-sling technique should also be compared with other antipronation methods, such as orthoses and medial wedges, as the low-dye method has been.¹² Strapping effectiveness depends on how complex a taping is applied and the materials used.^{9,12,13,15} Therefore, we recommend that stronger tape, such as an Elastikon product, be investigated in future research. Other areas of future study should include the low-dye technique using X-type plantar strips or reverse 6's that cross the ankle. These may add strength and support to make the technique more effective and longer lasting. Finally, given that we evaluated individuals who were not necessarily symptomatic, this study should be replicated in people with symptoms of plantar fasciitis.

CONCLUSIONS

Our results suggested the strapping techniques had a greater effect in redistributing plantar pressures than they did in changing navicular height. We believe more emphasis should be placed on shifting plantar pressures when discussing the effectiveness of arch-taping techniques for the relief of overuse symptoms. Both arch tapings effectively shifted pressures laterally, increasing pressures on the outside of the foot. Clinicians should consider the pros and cons of each taping application. Potential considerations are the fact that only the low-dye technique successfully reduced forefoot plantar pressures, but the navicular-sling technique tends to be more comfortable for patients. Plantar pressure seems to be a more clinically relevant measure; therefore, more attention should be placed on how arch-strapping techniques change pressure distribution.

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